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The Spine Journal 12 (2012) 817 823

THE SPINE JOURNAL

Review Article

Evaluation and management of combat-related spinal injuries: a review based on recent experiences

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Received 10 February 2011; revised 30 March 2011; accepted 28 April 2011

Abstract

BACKGROUND CONTEXT: The current approach to the evaluation and treatment of military casualties in the Global War on Terror is informed by medical experience from prior conflicts and combat encounters from the last 10 years. In an effort to standardize the care provided to mil itary casualties in the ongoing conflicts, the Department of Defense (DoD) has published Clinical Practice Guidelines (CPGs) that deal specifically with the combat casualty sustaining a spinal in jury. However, the combat experience with spine injuries in the present conflicts remains incom pletely described.

PURPOSE: To describe the CPGs for the care of the combat casualty with suspected spine injuries and discuss them in light of the published military experience with combat related spinal trauma.

STUDY DESIGN: Literature review.

METHODS: A literature review was conducted regarding published works that discussed the incidence, epidemiology, and management of combat related spinal trauma. The CPGs, established by the DoD, are discussed in light of actual military experiences with spine trauma, the present sit uation in the forward surgical teams and combat support hospitals treating casualties in theater, and recent publications in the field of spine surgery.

RESULTS: In the conventional wars fought by the United States between 1950 and 1991 (Korea, Vietnam, Gulf War I), the incidence of spine injuries remained close to 1% of all combat casual ties. However, in the Global War on Terror, the enemy has relied on implements of asymmetric warfare, including sniper attacks, ambush, roadside bombs, and improvised explosive devices. The increase in explosive mechanisms of injury has elevated the number of soldiers exposed to blunt force trauma and, consequently, recent publications reported the highest incidence of combat related spinal injuries in American military history. Wounded soldiers are expeditiously evacuated through the echelons of care but typically do not receive surgical management in theater. The current CPGs for the care of soldiers with combat related spinal injuries should be re examined in light of data regarding the increasing number of spine injuries, new injury patterns, such as lumbosacral dissociation and low lumbar burst fractures, and recent reports within the field of spine surgery as a whole.

CONCLUSIONS: American and coalition forces are sustaining the highest spine combat casu alty rates in recorded history and previously unseen injuries are being encountered with increased frequency. While the CPGs provide useful direction in terms of the evaluation and management

FDA device/drug status: Not applicable.

Author disclosures: ***AJS:*** Nothing to disclose; ***RAL:*** Grants: DARPA (I, Paid directly to institution/employer), DMRDP (H, Paid directly to institution/employer); ***JRH:*** Nothing to disclose.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

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1529 9430/$ see front matter Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.spinee.2011.04.028

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 SEP 2012	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Evaluation and management of combat-related spinal injuries: a review based on recent experiences	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Schoenfeld A. J., Lehman Jr. R. A., Hsu J. R.,	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**7**	

of combat casualties with spine injuries, such recommendations may warrant periodic re evaluation in light of recent combat experiences and evolving scientific evidence within the spine literature. Published by Elsevier Inc.

Keywords: Spine injuries; Combat; United States military; Spinal trauma

Introduction

Combat-related injuries to the spinal column have been documented in the historical record since the fifth century BCE [1]. The ancient Greeks accurately described cervical spine wounds sustained during combat, and the Egyptians devised means to attempt reduction of fractures and dislocations [1]. Until the age of gunpowder, however, most spine injuries sustained as a result of war were either immediately fatal or untreatable. With the advent of ballistic technology, and the development of modern medicine, combat-related spine injuries have become more survivable even as their incidence has increased [2]. For example, during Korea and Vietnam, spine injuries were encountered among 1% of all soldiers injured in combat [3,4]. This number increased to approximately 6% in the American air assault operation in Panama (1989) [5], and recent investigations regarding the modern battlefields in the Global War on Terror have documented a 7.4% incidence of spine trauma among all combat casualties [2,6].

The current approach to the evaluation and treatment of military casualties in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) is informed by medical experience from prior conflicts as well as the first decade of the Global War on Terror. In an effort to standardize the care provided to military casualties in the ongoing conflicts, the Department of Defense (DoD) has published more than 25 Clinical Practice Guidelines (CPGs), two of which deal specifically with the combat casualty sustaining a spinal injury. These are the CPGs for cervical spine evaluation [7] and the CPG on spine injury surgical management and transport [8].

At the present time, enemy tactics in both Iraq and Afghanistan continue to evolve; yet, an increased reliance on unconventional warfare has been observed, including the heavy use of improvised explosive devices, landmines, and suicide bombers [6,9,10]. This approach to combat, combined with the personnel protective equipment (army combat helmet and improved outer tactical vest) and up-armored vehicles deployed in support of US and coalition forces, has culminated in an increased prevalence of spinal injuries among service members in OIF and OEF [2,6]. The goal of this review is to describe the DoD CPGs for the care of the combat casualty with suspected spine injuries and discuss the guidelines in light of the published military experience with combat-related spinal trauma.

The DoD CPGs for cervical spine evaluation and the treatment of casualties with spine injuries

The guidelines for the evaluation and management of patients with spinal injuries are presently influenced by the echelons of care system used by the US and coalition forces to evacuate injured personnel from the battlefield to treatment centers in Europe or the United States where definitive care is administered [6,11]. Treatment for a wounded soldier begins at Echelon I, where combat medics deliver first aid at the point of injury and/or transport the casualty to a Battalion Aid Station. Echelon II consists of the forward surgical team, where wounded personnel can be evaluated by general surgeons and orthopedic surgeons. If necessary, surgery to save life or limb may be performed in this setting.

Echelon III facilities consist of combat support hospitals that are still present within the theater of operations. Combat support hospitals generally have advanced imaging capability with computed tomographic (CT) scanners at their site and also possess the capability of performing emergent surgical and orthopedic procedures [11]. On occasion, a neurosurgeon may be assigned to a combat support hospital, but doctrinally, dedicated spine surgeons and neurosurgeons are not part of the standard surgical staff [11]. However, typically there is at least one fellowship-trained orthopedic spine surgeon and one neurosurgeon in each combat theater at any one time. That being said, orthopedic spine surgeons are assigned to Echelon III facilities to provide general orthopedic care, with the administration of expert spinal care as an adjunct duty. It is important to recognize that, at the present time, spine surgical instrumentation is not readily available at each Echelon III facility within the combat zone and, by doctrine, wounded American or coalition soldiers do not receive surgical implants of any kind until they arrive at Landstuhl Regional Medical Center in Germany (Echelon IV) or a military treatment facility within the United States (Echelon V) [11]. Additionally, the potential for injured soldiers to be evaluated by magnetic resonance imaging (MRI) is not realized until Echelon IV or V [11]. It should be noted, however, that the medical evacuation process is so efficient that injured soldiers can arrive at Echelon IV or V facilities within 24 to 48 hours of a traumatic event.

The cervical spine evaluation CPG follows advanced trauma life support protocols in advocating a high level of suspicion for those individuals sustaining major

explosive or blast injuries, falls from a height, or ejection from a motor vehicle [7]. Wounded service members, and those complaining of neck pain or demonstrating obvious neurologic compromise, should be immobilized in the field with a cervical collar. Individuals with penetrating injuries from an explosion should also have a collar placed, but the CPG specifies that soldiers with isolated penetrating cervical injuries who are conscious and exhibit no neurologic involvement do not necessitate cervical immobilization [7]. The concern for a penetrating injury to the neck, with the absence of neurologic deficit, is that by applying external cervical immobilization, there may be an increased risk of unrecognized airway compromise during the evacuation process. Moreover, the CPG emphasizes that the lives of the casualty and those providing first aid on the battlefield are of the utmost importance, and movement of the casualty to a secure area outside the field of fire takes precedence over cervical immobilization.

Once the wounded soldier reaches a hospital environment, the CPG provides cervical spine evaluation algorithms for both the conscious and unreliable/obtunded patient. The algorithm for the conscious patient applies the National Emergency X-Radiography Utilization Study criteria [12] for cervical evaluation and recommends CT imaging if the patient has positive examination findings. In the event that a CT scanner is unavailable, the algorithm allows for three views of the cervical spine (anteroposterior, lateral, and odontoid views) as the primary means to facilitate collar removal. The CPG not only advises that the collar be retained in the event of radiographic abnormalities but also provides for continued immobilization in the face of normal imaging if the patient continues to complain of neck pain, limited range of motion, or paresthesias [7].

For the obtunded or unreliable patient, the CPG maintains that a CT study of the cervical spine must be performed. If the CT image is read as normal, the algorithm calls for collar removal [7]. The guideline allows for continued collar use only in situations where the CT scan is positive for injury or the study is deemed inadequate. The CPG declares that because of the lack of sufficient evidence regarding the effectiveness of MRI relative to CT for identifying occult cervical injuries, MRI is not considered a necessary adjunct in the clearance process for obtunded patients injured in combat [7]. Furthermore, in all instances, the CPG proposes that the determination of cervical clearance be made within 24 hours of injury [7]. Should prolonged cervical immobilization be deemed necessary, the trauma (extrication) collar should be replaced with an orthosis that provides sufficient padding and prevents the formation of decubitus ulcers.

The spine injury management and transport protocol incorporates the CPG for cervical evaluation and also adds that CT imaging or orthogonal views of the thoracic and lumbar spine should be obtained for patients with suspected injuries in those zones [8]. As MR evaluation is not available in theater, the CPG for spine injury management posits that a CT myelogram may be necessary for individuals whose presentation is consistent with spinal cord compression from a traumatic disc herniation or epidural hematoma [8]. The guideline also declares that treatment with high-dose methylprednisolone per the National Acute Spinal Cord Injury Study protocols [13] is not indicated in soldiers with combat-related spinal cord injuries. This is especially important in those soldiers who have open wounds, as the immunosuppression and side effects caused by the steroids can have deleterious consequences on wound healing. Additionally, the consensus opinion by the American Association of Neurological Surgeons in 2002 concluded that there is insufficient evidence to recommend for or against the use of the steroid protocol for spinal cord injuries [14].

The CPG advocates that a cervical collar is sufficient for transport in most patients with a cervical injury [8]. In certain situations, although these are not elaborated in the guideline, a halothoracic brace is also deemed acceptable. However, halo braces are not available at all Echelon III facilities. Soldiers with thoracic or lumbar injuries are to be immobilized in a vacuum spine board (VSB) and evacuated from theater by a critical care air transport team [8,11]. The VSB is similar to the ''bean bag'' device that is used for positioning in the operating room environment in that it wraps around the patient and can be inflated to decrease the motion occurring during the transfer/transport process. It does have some limitations although as there have been observed areas of superficial skin breakdown as well as patient anxiety and claustrophobia that sometimes necessitates intubation for transport. To date, there is no Level I evidence on the efficacy of the VSB.

The CPG is vague with regard to the possibility of surgical intervention ''in theater.'' Concerns regarding the long-term complications associated with infected implants and operating room resource utilization have generally led practitioners to refrain from instrumenting the spine or decompressing an unstable spine injury until the wounded soldier reaches Echelon IV or V [11]. The CPG, however, declares that optimizing the patient's final neurologic result should be the primary goal and provides for the possibility of decompression and instrumentation in select situations, such as a hemodynamically stable patient without other wounds, no contaminated spinal injury, and a progressive neurologic deficit [8]. Such a situation could arise, for example, in a helicopter pilot with progressive neurologic deficits from a closed lumbar burst fracture sustained in a crash (Fig. 1). In the case of penetrating spinal trauma, the CPG allows for surgical debridement and emergent decompression in the case of cauda equina syndrome, progressive neurologic deterioration, incomplete spinal cord lesion when fragments are present within the spinal canal, and cerebrospinal fluid leak [8]. The guideline, however, also cautions that decompression in theater without the potential for instrumented stabilization should only be performed after great consideration and possibly only following agreement between the treating surgeon and the chief of

Fig. 1. Sagittal computed tomographic reconstruction demonstrating T11 and low lumbar L5 burst fracture in an active duty service member injured in combat.

trauma at an Echelon III facility [8]. Should surgical intervention be considered and undertaken, communication between the Echelon III and IV/V facility is paramount for continuity of the care plan. On occasion, patients with a progressive incomplete neurologic deficit can be decompressed and instrumented posteriorly in theater; however, there is no anterior reconstruction capability at Echelon III hospitals, and access surgeons are not always available because of the surgical case load and casualty flow.

Combat-related spinal injuries in OIF and OEF

As indicated above, for the better part of military medical history, spinal injuries sustained during warfare either resulted in immediate demise or could not be effectively managed [1,2]. Although considered rare relative to other combat-related injuries, the incidence of war-related spine trauma has continued to increase over the course of the 20th century [2]. In the conventional wars fought by the United States between 1950 and 1991 (Korea, Vietnam, Gulf War I), the incidence of spine injuries remained close to 1% of all combat casualties [3,4,15]. However, in both OIF and OEF, the enemy has relied on implements of asymmetric warfare, including sniper attacks, ambush, roadside bombs, and improvised explosive devices [2,6,9 11]. This increase in explosive mechanisms of injury relative to gunshot has elevated the number of soldiers exposed to blunt force trauma, and the use of enhanced vehicular and body armor has allowed soldiers to survive blasts that would have proven fatal in prior conflicts [2].

Both these factors have contributed to the rise of combat-related spinal injuries as appreciated in the work of Kelly et al. among others. These authors compared injuries sustained by 486 soldiers killed in combat in OIF and OEF in 2003 to 2004 to 487 killed during 2006 [9]. Explosions were the predominant mechanism of injury for both time periods, but there was a statistically significant increase in the number of individuals killed because of explosion between 2003 2004 and 2006 [9]. Spinal cord injury was documented as the cause of death in 1% of the cohort killed during 2003 to 2004 and 2% of those killed in 2006. Similar findings were also presented in the work of Bell et al. [16], who examined the cases of 408 patients with neurologic injuries incurred during combat in OIF (2003 2008). Once again, explosions were the predominant injury mechanism with 56% of the cohort injured by blasts. In this series, 40 individuals (9.8% of the cohort) were found to have sustained injuries to the spinal cord or vertebral column [16].

Two studies have specifically targeted cervical injuries resulting from penetrating wounds caused by combat [17,18]. Driscoll et al. [17] examined the records of 52 soldiers evacuated to Walter Reed Army Medical Center as a result of penetrating cervical injury from 2003 to 2005. Spinal column involvement was evident in only 6% of the cohort, but neurologic compromise was documented in 17%. Sixty-five percent had received emergent neck exploration in theater. Ultimately, 8% of soldiers in this study were found to have permanent neurologic deficits, and 2% died as a result of their injuries [17].

In the work of Ramasamy et al. [18], the cases of 90 casualties with penetrating cervical trauma were reviewed. The cause of injury was explosion in 73% of the cohort and gunshot wounds in 27%. The cervical spine was involved in 22% of cases, and 90% of soldiers with spinal injury associated with their penetrating wounds died [18]. Only 3% of the casualties considered to have unstable spine injuries were able to reach a hospital facility alive, and ultimately only two individuals survived. Both patients, however, were found to have some degree of neurologic impairment, and one patient was tetraplegic. In light of their findings, Ramasamy et al. maintained that few soldiers with penetrating neck trauma would benefit from cervical immobilization and advocated instead for expeditious evacuation claiming that it is "… neither prudent nor practical to immobilize (sic) all patients with penetrating injury to the neck under battlefield conditions" [18].

Recently, Schoenfeld et al. [2] conducted an analysis of spine wounds among the soldiers of a US Army Brigade Combat Team assigned to OIF during the Iraq War Troop Surge of 2007. As the Brigade Combat Team is presently the military's basic deployable unit, these authors hypothesized that their data represented the best available evidence

regarding the incidence and epidemiology of spine injuries in the current conflicts. In this cohort of 4,122 soldiers deployed to a combat zone, Schoenfeld et al. [2] documented a spine combat casualty rate of 7.4%. This represents the highest documented figure for the incidence of combat-related spinal injuries in American military history. The cervical spine was the most commonly injured segment (48% of cases), whereas lumbar injuries occurred in 45% [2]. Closed fractures were present in 21% of those with spine wounds, whereas open fractures were documented in 7%. Explosive mechanisms were responsible for 83% of all spine injuries in the series [2].

It is important to note that most service members with survivable spine wounds presented with injuries similar to those encountered in a civilian trauma setting (ie, compression fracture, lumbar burst fracture, flexion-distraction injury) [2]. However, recent experience from Walter Reed Army Medical Center has shown an increase in unusual spinal wounding patterns, including low lumbar burst fractures (Fig. 1) and lumbosacral dissociations (Fig. 2) [19]. These injuries result from the force of blast mechanisms imparted to the axial skeleton of soldiers as they are securely seated in uparmored vehicles.

Fig. 2. (Top) Axial computed tomographic (CT) image of a lumbosacral dis sociation sustained during combat. (Bottom) Sagittal CT image of the same service member depicted in Top demonstrating a lumbosacral dissociation.

Current challenges and opportunities for the future

Recent publications regarding the experiences of US and coalition forces on the battlefields of the Global War on Terror necessitate new evaluation of the CPGs regarding cervical spine clearance and the management of combat casualties with spinal injuries. Foremost, it should be recognized that because of a combination of enemy tactics and heightened personnel protective measures, a greater number of spine injuries are being witnessed in the present conflicts than ever before [2]. Rather than being relegated to a rare event over the course of a deployment, practitioners and medical units operating in combat theaters should expect to see patients with complex spine injuries and be properly equipped to deal with such casualties. The possibility of successful surgical intervention for personnel with progressive neurologic deficits, for example, would be enhanced by the availability of spinal instrumentation sets within theater. Indeed, the spine injury management CPG alludes to this, stating ''Improvements in spinal instrumentation systems available in theater may broaden the surgical options available to the spine surgeon'' [8]. Additionally, it is imperative to standardize instrumentation and implant sets, so that if emergent surgery does occur in theater, the Echelon IV and V facilities have the means to revise components, if necessary.

Second, some consideration should be given to the protocols inherent in the cervical evaluation CPG in light of recent publications within the spine literature. At present, the guideline calls for cervical spine clearance in the obtunded or unreliable patient after a negative CT study [7]. Several recent reports, however, have called such recommendations into question [20 22]. Although multiple investigations support the notion that a single negative CT study is sufficient to clear the cervical spine [7], other authors contend that MRI represents the true ''gold standard'' for the evaluation of occult cervical injury in the obtunded patient [22]. Moreover, in a recent meta-analysis representing 1,550 patients injured by blunt trauma, Schoenfeld et al. [21] demonstrated that CT imaging of the cervical spine alone was incapable of detecting all clinically significant injuries. In this study, 6% of clinically meaningful injuries were missed on CT evaluation with 1% necessitating surgical intervention [21]. Additionally, it should be recognized that most modern studies endorsing the use of stand-alone CT for cervical clearance are performed with helical multidetector scanning equipment [20], the likes of which are not typically available in the combat zone, even at Echelon III facilities.

In light of these findings, it may be more prudent to incorporate the treatment approach advocated by Anderson et al. [20] in the cervical spine CPG. Instead of dividing patients into conscious and unreliable/obtunded, Anderson et al. [20] recommended the categories of asymptomatic, symptomatic, temporarily unassessable, and obtunded. Asymptomatic patients may be cleared using the National Emergency X-Radiography Utilization Study protocol [12,20]. Symptomatic patients are examined using plain film radiographs, CT, and/or MRI as deemed necessary. Temporarily unassessable patients are those with short-term cognitive deficits or distracting injuries who are expected to be conscious and able to co-operate with an examination within 24 to 48 hours [20]. These patients are left in a collar for the 24 to 48-hour period while their other injuries are treated and/or cognitive function returns. They may then be evaluated as asymptomatic/symptomatic patients or revert to the obtunded category if they are still unassessable after 48 hours.

Individuals in the obtunded category require CT and/or MRI before the determination of cervical clearance [20]. In these situations, the need to remove the cervical collar is driven by concerns regarding the potential for elevated intracranial pressures, aspiration, airway compromise, and the formation of decubiti [20 22]. Fortunately, many of these adverse events are rare in the young healthy population serving in the armed forces of the United States and its coalition partners. Except for individuals with closed head injury or cranial trauma, the potential for significant side effects from 24 to 72 hours of cervical immobilization in an orthosis is likely less than the risk of catastrophic neurologic injury from a missed unstable spine. Especially in light of the rapid medical evacuation process from the combat zone to Echelons IV and V, where MRI is available, it may be more prudent to delay collar removal in an unreliable or obtunded patient until advanced CT or MRI can be performed [21,22].

Lastly, as new injury patterns, such as low lumbar burst fractures and lumbosacral dissociation, are being seen with increased frequency in the present conflicts [19], attention should be given to documenting protocols, algorithms, and best practices for the evaluation and management of soldiers sustaining such trauma. Because these types of spinal injuries are exceedingly rare in the civilian environment, the best available evidence regarding their diagnosis and treatment will derive from military treatment centers. More research regarding these issues must be conducted in the future, and new guidelines should be developed, particularly with regard to lumbosacral dissociation, to inform the care of service members who sustain these wounds on the battlefield.

Conclusion

Currently, American and coalition forces are sustaining the highest spine combat casualty rates in recorded history. In addition, previously unseen injury patterns, such as lumbosacral dissociation and low lumbar burst fractures, are being encountered with increased frequency. Although the DoD CPGs provide useful direction in terms of the evaluation and management of the combat casualty with a spine injury, these guidelines may warrant periodic re-evaluation in light of the recent experiences with spine injuries on the battlefields of OIF and OEF and continually evolving scientific evidence. Ultimately, more substantial research must be conducted, particularly with respect to the global military experience with spine casualties in the last decade, before definitive conclusions can be reached and appropriate recommendations made.

Supplementary data

This article will have an accompanying commentary. Please visit the online version of *The Spine Journal* at www.TheSpineJournalOnline.com, and at 10.1016/j.spinee.2011.04.028.

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